



Nondestructive Evaluation Using Fiber Gratings for “Strain Imaging”

Eric Udd

Blue Road Research

376 NE 219th Avenue

Gresham, Oregon 97030

503 667-7772, Fax 503 667-7880

eric@bluerr.com www.bluerr.com

Report Documentation Page			Form Approved OMB No. 0704-0188		
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 13 JUL 2004		2. REPORT TYPE		3. DATES COVERED -	
4. TITLE AND SUBTITLE Nondestructive Evaluation Using Fiber Gratings for			5a. CONTRACT NUMBER F04611-02-C-0007		
			5b. GRANT NUMBER		
			5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S) Eric Udd			5d. PROJECT NUMBER 3005		
			5e. TASK NUMBER 02AG		
			5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Blue Road Research,376 NE 219th Ave,Gresham,OR,97030			8. PERFORMING ORGANIZATION REPORT NUMBER		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSOR/MONITOR'S ACRONYM(S)		
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)		
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT Arrays of multi-axis fiber grating sensors have been embedded into composite demonstration articles and used to support the identification and localization of both cut tow and Teflon tape defects. This presentation will overview the characteristics and performance of multi-axis fiber grating strain sensors to perform strain imaging and comparisons will be made to ultrasonic and eddy current techniques. Issues that will be addresssed will include the distance over which damage may be detected via "strain imaging," "strain imaging" through successive composite layers, and "strain imaging" through optical fibers. Strain images from cut tow and Teflon tape defects are distinctly different. The embedded multi-axis fiber grating strain sensors may be used to monitor both global strain characteristics such as deformation of the cylindrical composite demonstration article under pressure as well as local damage events that may be impacts. This paper will report progress on multi-axis fiber grating strain imaging systems and future plans.					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES 23	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Acknowledgements

Blue Road Research would like to acknowledge funding support for this research effort from the SBIR Phase II Air Force Contract F04611-02-C-0007, “Fiber Grating Sensor Systems to Determine Motor Case Damage”. Dr. Greg Ruderman is the Technical Program Monitor

Strain Imaging

- Localization and identification of damage through detailed measurement of strain fields
- Information provided in seconds on demand with target accuracies comparable to ultrasound or eddy current
- Enabling technologies, multi-axis fiber grating strain sensors, improved spectral detection methods, processing algorithms

Strain Imaging Demonstration

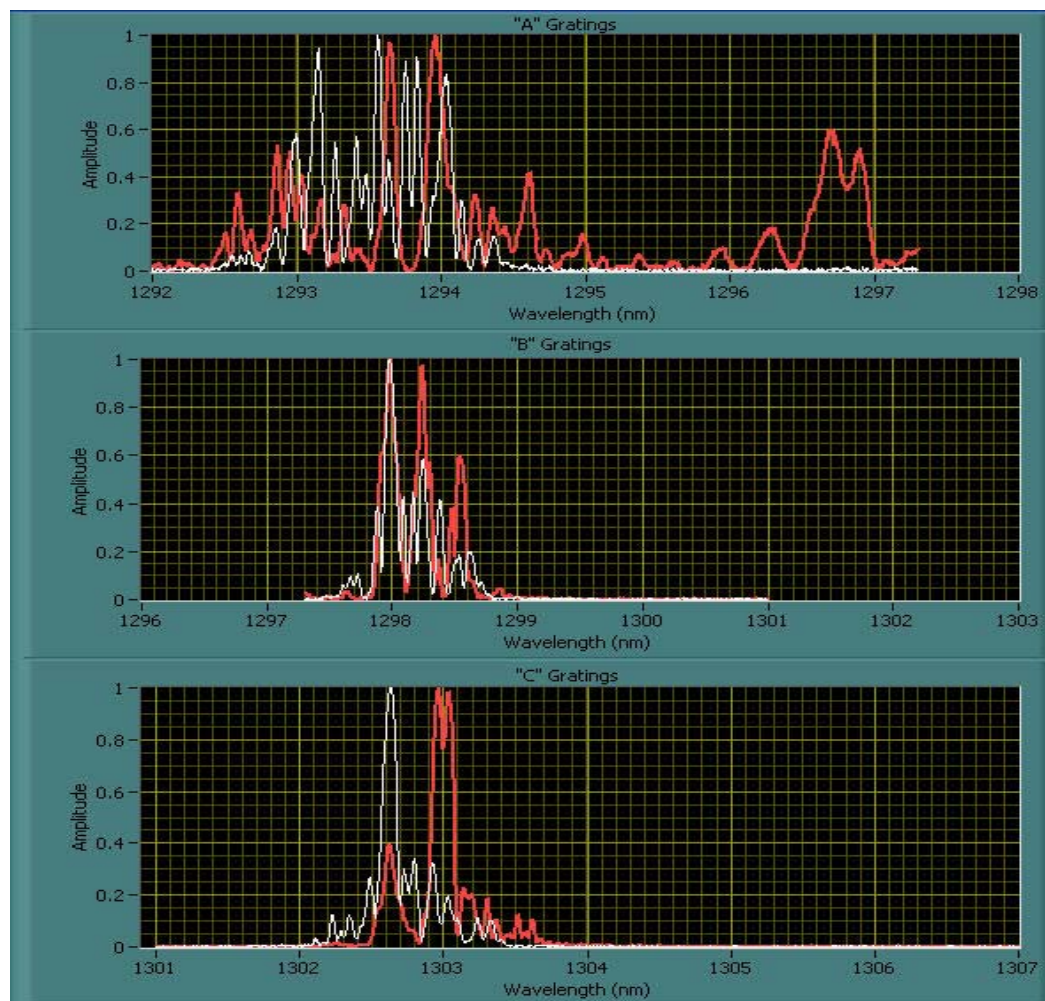
- Composite rocket motor filled with inert propellant
- Impacts at 5, 10, 15, and 20 ft-lbs energy
- Fiber arrays in region of damage read out with Blue Road Research Strain Imaging system and damage location plots shown

Strain Imaging Bottle Impact Test



Strain Imaging Bottle Impact Test

Grating Spectra Before Impact



Strain Imaging Bottle Impact Test Before Impact



Strain Imaging Bottle Impact Test

5 ft-lb Impact



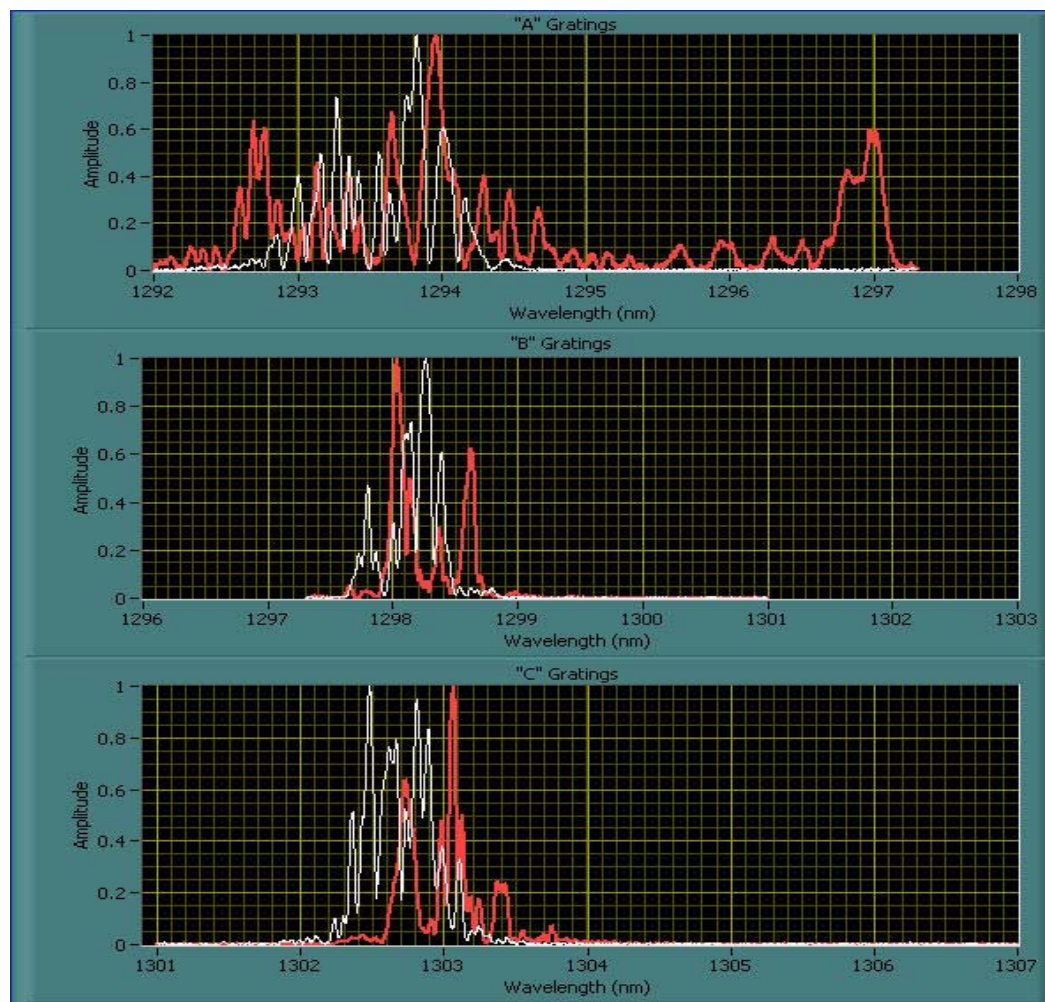
Strain Imaging Bottle Impact Test

5 ft-lb Impact



Strain Imaging Bottle Impact Test

Grating Spectra After 5 ft-lb Impact



Strain Imaging Bottle Impact Test After 5 ft-lb Impact



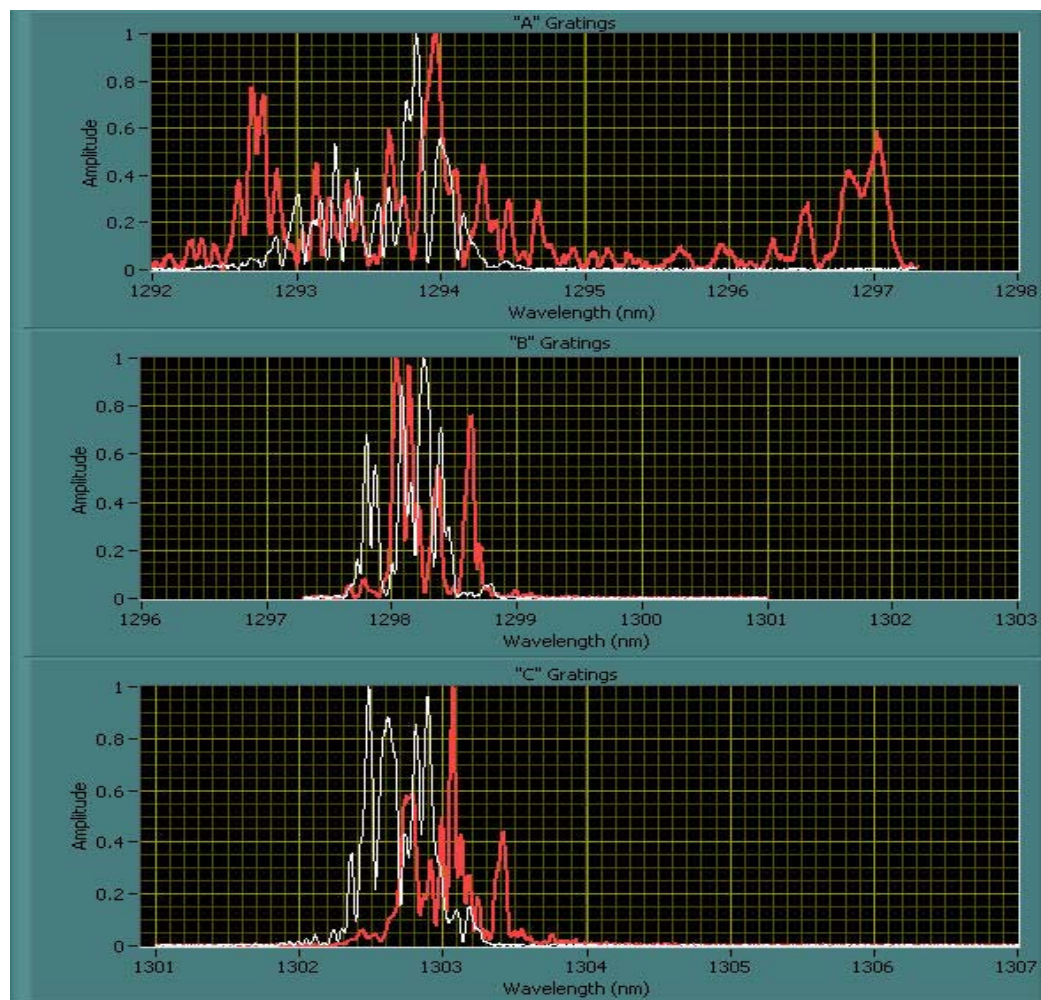
Strain Imaging Bottle Impact Test

10 ft-lb Impact



Strain Imaging Bottle Impact Test

Grating Spectra After 10 ft-lb Impact



Strain Imaging Bottle Impact Test After 10 ft-lb Impact



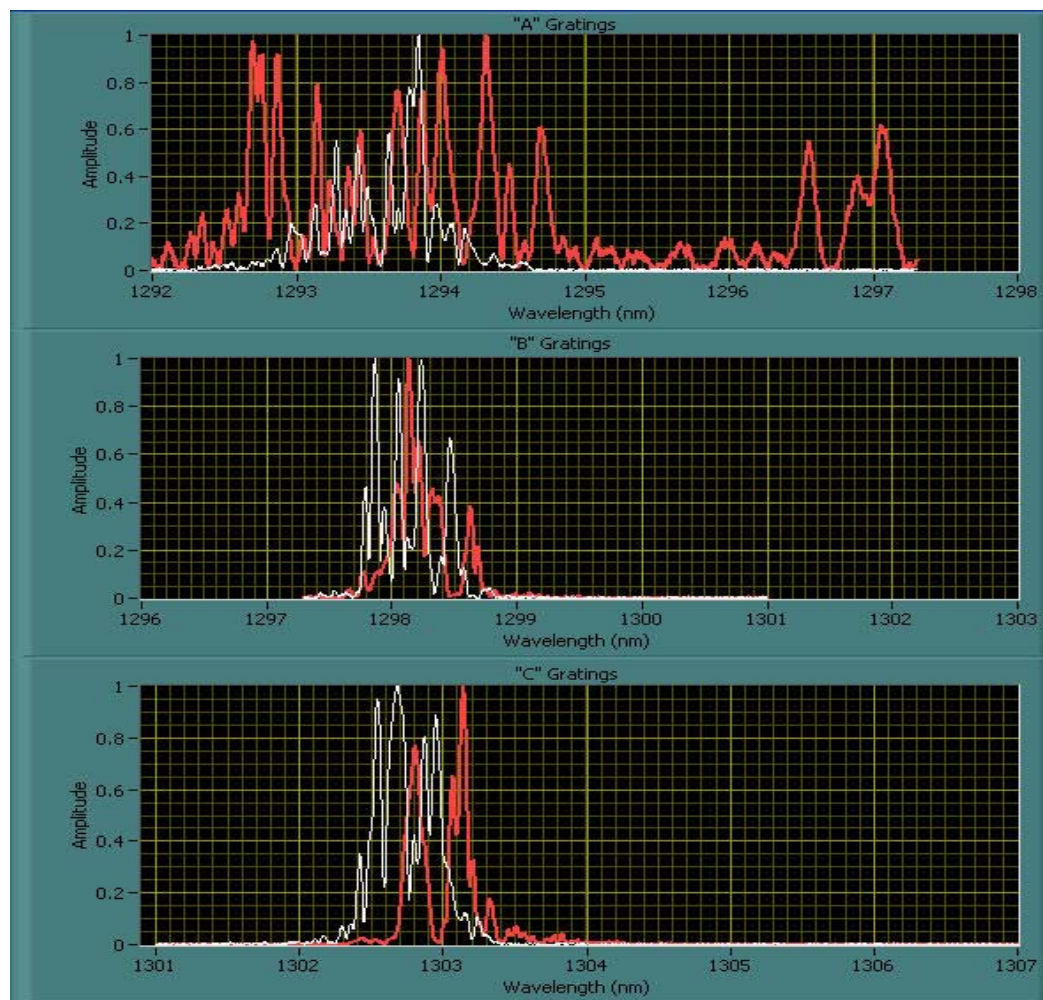
Strain Imaging Bottle Impact Test

15 ft-lb Impact



Strain Imaging Bottle Impact Test

Grating Spectra After 15 ft-lb Impact

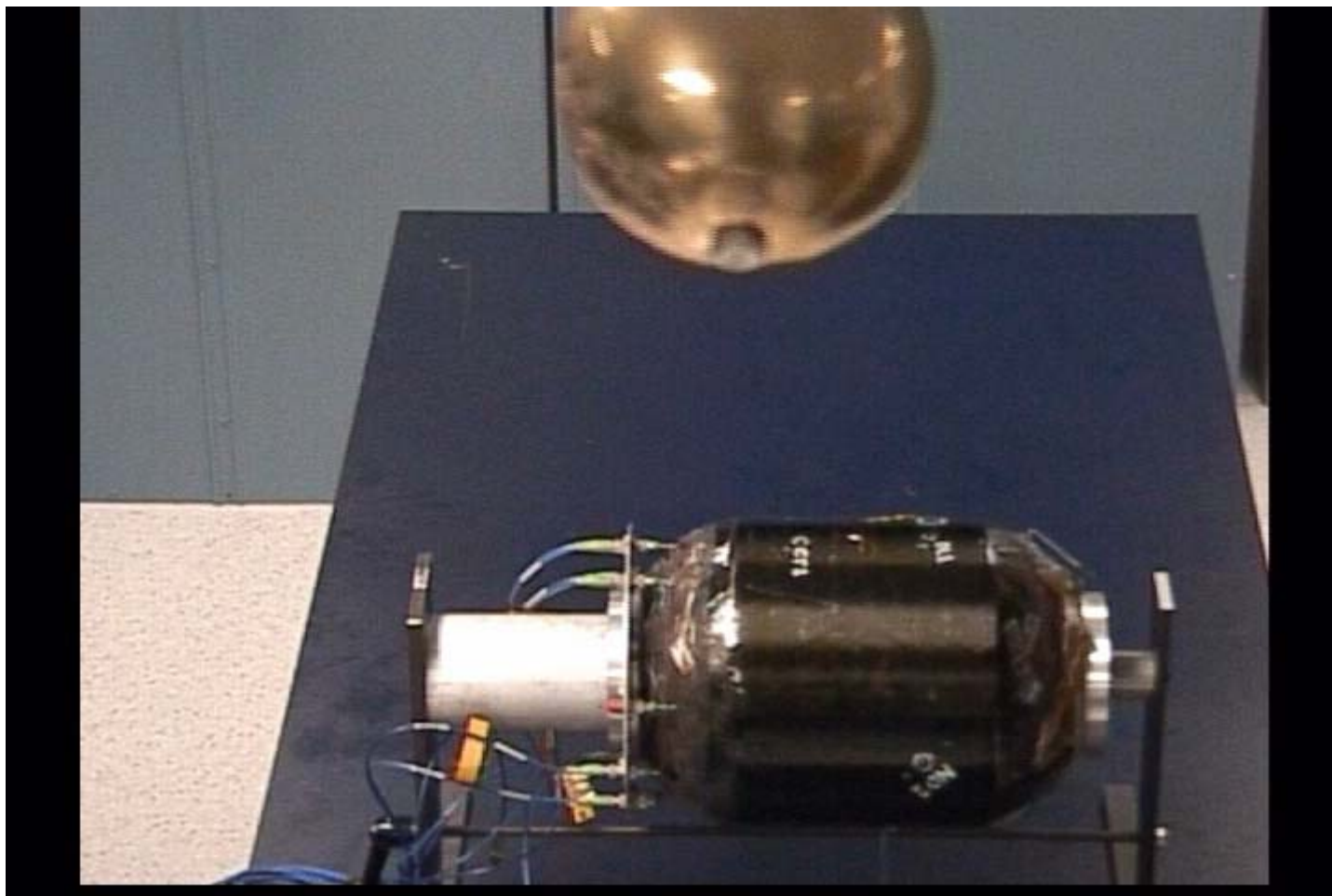


Strain Imaging Bottle Impact Test After 15 ft-lb Impact



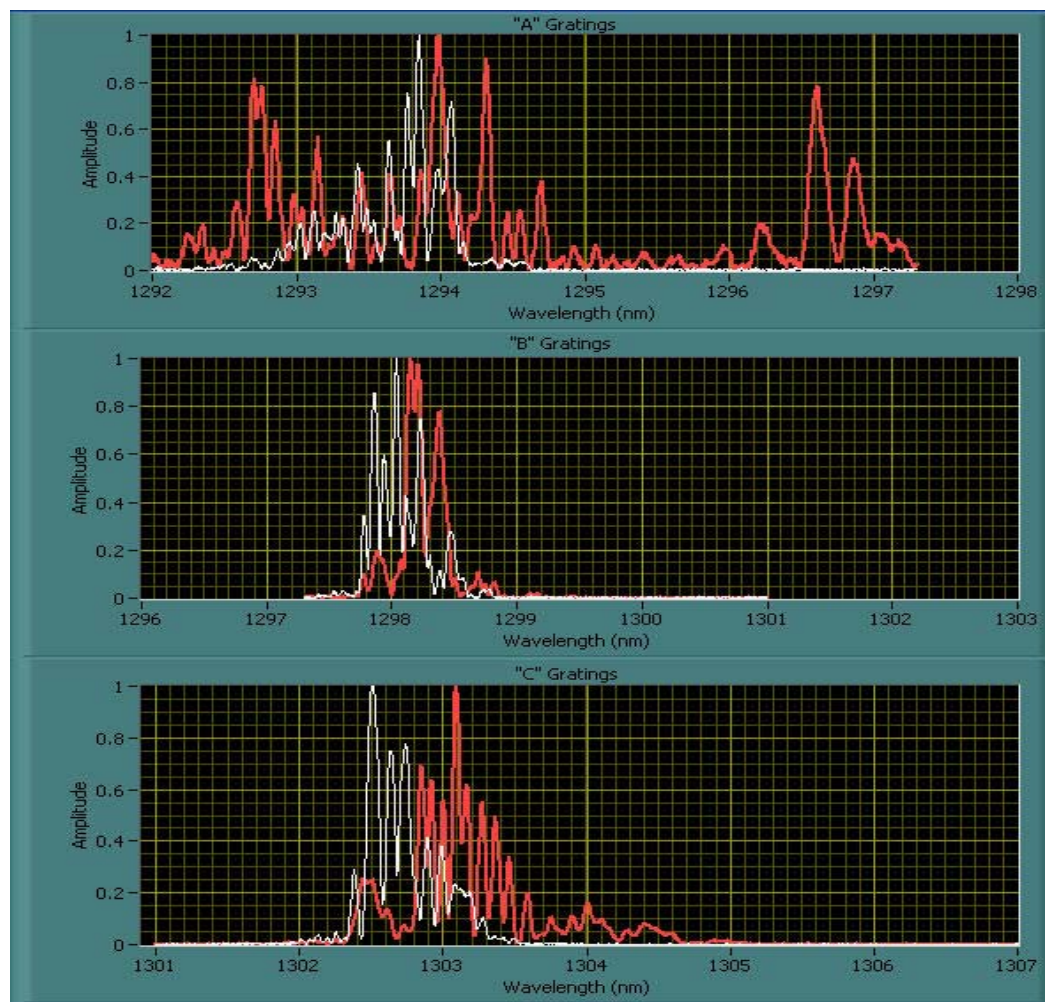
Strain Imaging Bottle Impact Test

20 ft-lb Impact



Strain Imaging Bottle Impact Test

Grating Spectra After 20 ft-lb Impact

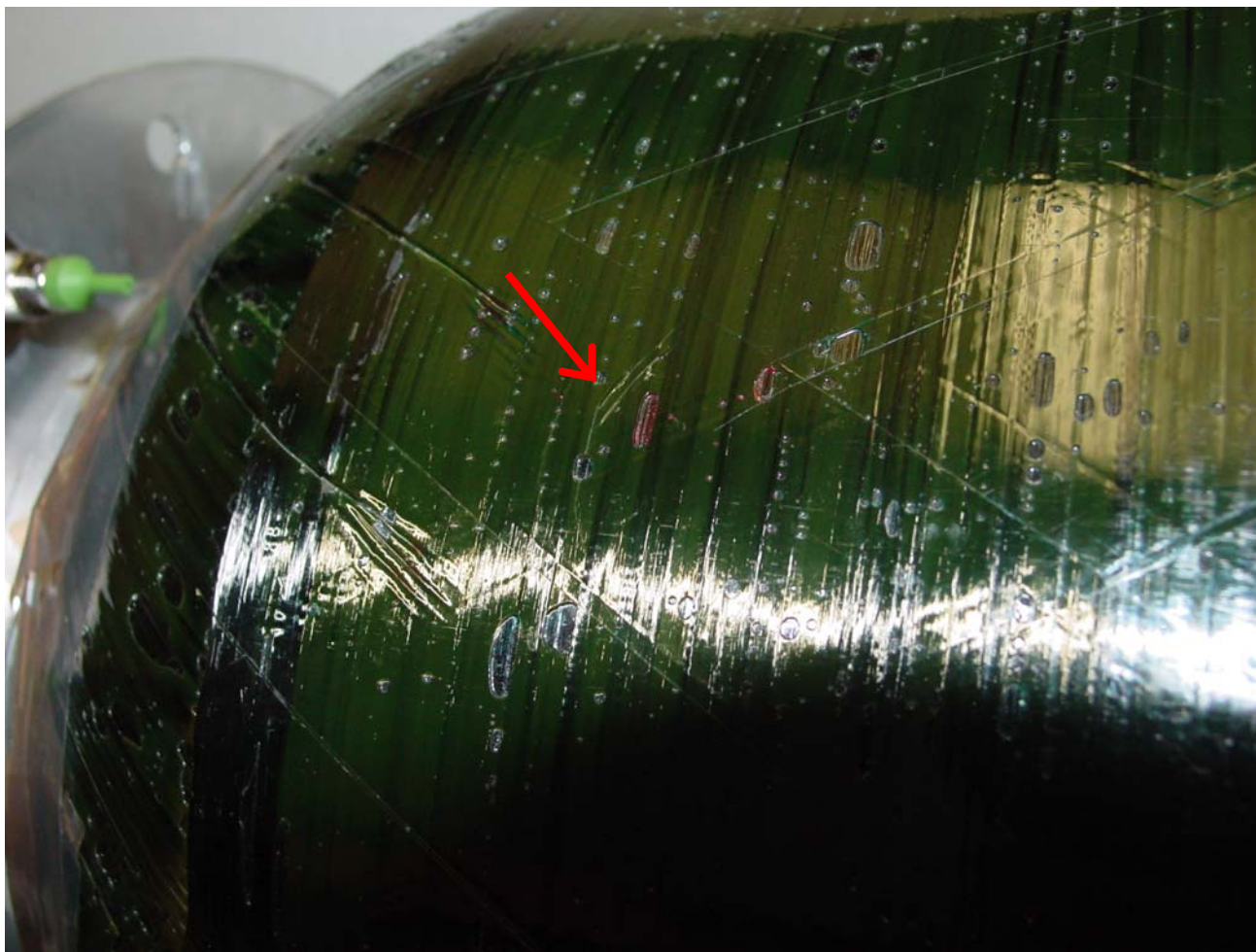


Strain Imaging Bottle Impact Test After 20 ft-lb Impact



Strain Imaging Bottle Impact Test

Damage Area After All Impacts



Strain Imaging Bottle Impact Test

Damage Area After All Impacts



Summary

- Multi-axis fiber grating sensors successfully used to perform “strain imaging” to locate damage
- Multiple impact levels visible
- Damage detected with “strain imaging” that could be missed via physical inspection